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RESEARCH ARTICLE

Wireless Sentinel Surveillance in Digital Epidemiology and Transdemic Management

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ABSTRACT:
Throughout the history of science, technological innovation has facilitated improved understanding of our human nature and characteristics and our complex relationships with our environment. In medical history, such innovations have allowed a more accurate and nuanced ability to intervene in promoting health and preventing and treating disease and disorder. Of course, the ability to correctly apprehend the meaning of the observations that are available to us through innovative breakthroughs is dependent on the conceptual adequacy of our endeavor. This conceptual adequacy has shown evolutionary progress and broadening, partially achieving the goal of consilience, articulated by the evolutionary biologist EO Wilson (1). The aim of this paper is to explore this expanding base and then describe an exemplar of our greater ability to understand and intervene in pursuit of global health. The scope of inquiry ranges from individual remotely obtained data to global health evaluation by advanced computational methods, with the objective of clarifying the conceptual, methodological and operational aspects of such a systemic approach.

Keywords: Transdemic, digital epidemiology, global health, hardware/software/networked system, wearable devices, heart rate variability, complex adaptive systems, i4P medicine, deep learning, consilience, edge computing, digital twinning, psychological science, policy implications.

Introduction:

Our earliest endeavors in health and healing came from an ability to accurately observe both human nature and our complex transactions with our natural environments. As our ability to observe became more detailed and penetrating, a scientific understanding emerged and provided methodologies and technologies that were based on physiological and biochemical knowledge. This initially reductionistic approach was very helpful in addressing a variety of health concerns and issues, but recently a broader scientific approach to the functioning of complex adaptive systems has expanded our therapeutic abilities, so that increasingly sophisticated interventions are possible, party due to the contributions of increasingly powerful computational techniques of information acquisition and processing, network analytic science and artificial intelligence. Such approaches can obtain and analyze very large data sets of human biological and other information, although artificial intelligence is in a very preliminary stage of development.

This evolution has allowed a more detailed and fine-grained view of human functioning, which in medicine has been called precision medicine, personalized medicine and recently, i4P medicine (Hood (2); Drury (3)). The latter refers to an Integrated Prescriptive, Preventive, Personalized and Participatory medicine which expands beyond the largely genomic focus of the first two approaches, to encompass not only physiology and anatomy, but psychological and socio-cultural variables. Hood and colleagues have contrasted this approach with O4 medicine which over tests, over diagnoses, over treats and over charges–a stinging critique of problematic aspects of the so-called "medical-industrial complex". As exemplified by the healthcare systems in the United States, the highest costs for healthcare are linked to many poor, inequitable and even dangerous outcomes, so the critique must be taken seriously.

The expanded approach described above also integrates the key role of evolutionary and historical understanding, since many current diseases and conditions are deemed "diseases of civilization" which are mismatches between long term remnant human characteristics from the environment of evolutionary adaptation of homo sapiens and the conflicting demands and dangers of the contemporary world, obesity being a prominent example of overconsumption of nutrition which is highly available to many in the global "developed" nations who then suffer many adverse health effects from that consumption. This has led some critics to identify "over developed nations" who suffer these mismatch disorders. Another important development from modern evolutionary science is that individual genetic evolution has been joined by group and socio-cultural evolution, as well as the recognition of the importance of epigenetic influences on phenotypic expression (DS Wilson, 4).

A further component of this expanded model is the recognition of the central role of attachment phenomena in humans and other primates (Bowlby, 5). It is difficult and even impossible on some occasions to understand and treat some disorders without a determination of the individual's attachment history and attachment style.This field has clarified the often stereotypical and misguided explanations of psychoanalysis with a more accurate and effective neurobiological approach.

Global Health and Epidemiology

The complex model described above is applicable to global health and its key scientific constituent, epidemiology. As emphasized by the complex adaptive systems (Capra and Luisi,6) approach, epidemiology emerged as a scientific field by astute observations made by systems oriented thinkers who noted, for example, the role of water pollution in the archetypical case of John Snow's determination that the Broad Street pump was the major contributor to a serious cholera outbreak in London. The epidemic was effectively terminated by removing the pump handle, an example of non medical intervention (NMI).

The centuries old practice of variolation in China and India was observed critically by a cadre of intelligent lay people, including President Thomas Jefferson and evangelist Cotton Mather, and their support led to the eventual emergence of vaccination, which has saved countless millions of lives. Fleming's observation of the "accidental" antibiotic role of penicillin and BF Skinner's development of intermittent schedules of reinforcement when he ran short of food pellets to reward his murine subjects are further examples of the value of close critical observation of complex systems in interaction.

It should be noted that terms from complexity theory (Capra and Luisi, 6 Mitchell,7; Sole and Goodwin,8) have relevance for understanding of both global health and epidemiology. Emergence refers to self-organizing phenomena that occur under certain environmental conditions and are not "directed" by any higher order intervention. A commonly observed example is the phase transition that occurs when water is cooled below 0 degrees Celsius. Such phase transitions, or "tipping points" are subject to our understanding and can elucidate otherwise apparently inexplicable phenomena such as the murmuration of starlings and other birds, a flocking or schooling determined by relatively few simple rules followed by the "agents" that comprise the system. Another salient feature of complex adaptive systems, which include all living organisms, is their non-linear characteristics. This contrasts radically from the linear characteristics of machines and other non living entities, which are subject to simpler mechanical modeling and simple cause and effect analysis. The study of non-linear functions and systems is still in the relatively early stage of development and use of such approaches in epidemiological modeling is far from perfect. The well known estimate by the Institute for Health Metrics and Evaluation of 60,000 total US fatalities from the COVID-19 transdemic is a sad example. Another observation which has entered popular awareness to some extent is the extreme sensitivity of complex systems to initial conditions, where it has been said "a butterfly flapping its wings in the Amazon may cause a drought in Singapore". This phenomenon is a contributing factor to the well known difficulty in advance weather prediction and is known as determinant chaos, a stochastic process which cannot predict with total certainty a given outcome in complex adaptive systems.

The mixed entomological root of pandemic is from the ancient Greek demia, meaning disease and demos, meaning the people. Epidemic and endemic are well known but the useful term syndemic (or synergistic pandemics) refers to two interacting pandemic phenomena which influence and possibly potentiate each other. The use of the term to illustrate the role of social factors such as income disparity on the course of COVID-19 outcome is a valuable construct, but consistent with the expanded model of health and human functioning proposed above, the term transdemic refers to the identification of relevant variables that interact to modulated the course and outcome of disease and disorder morbidity and mortality. Clearly, this term extends beyond the confines of strictly biomedical entities to include social pathologies such as income disparity, racism, gun violence and even disinformation campaigns. Thus an accounting of a COVID-19 transdemic would include not only the nature of the SAS Cov2 virus with its myriad variants, but a careful assessment of socio-cultural variables including health system characteristics, income disparity and poverty factors, racism and other ethnic discrimination, environmental factors related to climate catastrophe, and psychological variables incluing worldview, common stress and coping mechanisms, and cognitive biases, among others. Use of this expanded conceptual approach will facilitate a more nuanced and targeted effort in transdemic management., although admittedly, more powerful and robust big data analytic strategies will be required due to the multivariate nature of the model.

The inclusion of psychological variables is particularly important since a major weakness in effective management of illness and disease is the ignoring or downgrading of personal cognitive and affective variables. A sad but illuminating example is the case of Dr. Anthony Fauci's being infected with the SARS Cov2 virus. Despite his superior knowledge and experience with infectious disease, including the key role of NMIs such as masking, he attended a medical school class reunion and while he entered wearing an N95 mask, he took the mask off, believing that "it might make my classmates uncomfortable, and that's when I was infected", a possibly life-threatening occurrence for an older individual. Perceived social psychological factors undoubtedly influence many types of unhealthy behavior. Another flagrant incidence of anti-psychological bias is provided by a comment by Andy Slavitt in his otherwise excellent "Preventable" that "the core issues were as much psychological and behavioral as scientific", clearly indicating that psychological and behavioral factors are not scientific. A deeper understanding of psychological science will facilitate its skillful and successful application to crucial even existential issues such as COVID-19 and Climate Catastrophe.It is unquestionable that psychological and behavioral factors play a major role in matters such as the personal functioning of inept or incompetent leaders and the attentive reception and acceptance antisocial disinformation propagated by social and news/entertainment media.The distinguish social psychologist Baruch Fishoff of Carnegie Mellon University has observed that "in general, people care much more for their own immediate life experience and circumstances than for statistics and figures" and therefore much public health and risk communication may be ill targeted. The divided and increasingly tribal nature of many cultures has made appeals to compassion, altruism and concern for the "greater good" much less salient than concern for "what's in it for me and my tribe". Of course, encouragement of such narrow fear mongering by authoritarian, narcissistic politicians and commercially dependent media, who thrive by the motto "if it bleeds, it leads" only exacerbates not only public health management but crises of all types, the most important of which, climate catastrophe, may be existential.

While the multivariate nature of this proposed model of global health may seem overwhelming, this territory is familiar to public health professionals who have had to struggle to find a robust prescriptive model that leads to actionable policies and practices, they have also faced increasing resistance and even threats to their well being and lives. While not completely elaborated, the proposed model is empirically based and subject to scientific maturation.

Digital Epidemiology Exemplar

A proposal recently published by our group (Drury, 3) has outlined a systemic approach to addressing these issues in operational terms. In this context, digital epidemiology refers to the use of computers, personal devices and other electronic infrastructure to pursue goals of epidemiology, understood here to be the study of factors that influence morbidity and mortality in populations. The system which we propose is an integrated software/ hardware/ networked analytic approach which takes advantage of the increasing popularity of personal devices with wearable biosensors. While the majority of these devices are platformed on relatively obtrusive wrist and waist bands for purposes of athletic and fitness training, some watches are perceived as less obtrusive and even as cosmetic additions to the wearer's appearance. Many of these devices have either inadequate or unknown design properties for reliability and validity for clinical purposes, and manufacturers frequently refuse to release specific performance data. There is accumulating evidence showing that some of these devices do produce accurate data (Drury, 9 ; Shaffer and Ginsberg, 10). While most devices monitor activity and heart rate, such raw data sources are not highly meaningful in isolation and those that purport to measure more global concepts such as “stress” or “readiness” are not rigorously defined.

We advocate a more data based, empirically studied approach which collects high fidelity longitudinal data on temperature, interbeat heart rate data, blood oxygen saturation and three dimensional accelerometer. These data are acquired through a proprietary ring (Oura) and transferred via Bluetooth to cell phones, which have a very high market penetration worldwide, frequently even when running water and electricity are unavailable.These data are then transferred to specialized algorithms that include AI analysis of HRV and other parameters. A very promising alternative described by Dean et al (11) is asynchronous distributed data flow for machine learning workloads to process patient data clouds, following the deep learning approach advocated by Topol (12). Such analyses are then made available to appropriate public health authorities, and the individual patient may receive health behavior prompts. It should be noted that these variables are centrally involved in the early diagnosis of COVID-19, but are relevant to a wide variety of conditions and represent a very high fidelity vital sign monitoring process. Based on the preponderance of supportive evidence, the most important variable derived is heart rate variability, which is calculated by analyzing both time and frequency domain measures of interbeat interval (R to R wave ECG) as well as non-linear statistics. Our group has presented a proof of concept study which shows how interbeat interval data can be algorithmically analyzed to create relative risk scores for the presence of active inflammatory activity (Jarczok, 13). This approach is conceptually grounded in the seminal work of Porges’ Polyvagal Theory (14) and Thayer’s Neurovisceral theory (15) and massive data shows HRV to be a health biomarker which has detected to presence of COVID-19 up to seven days before the appearance of symptoms in symptomatic patients. HRV also has been demonstrated to be a sensitive biomarker for many other diseases and even measures of positive human functioning (Drury, 3). It is proposed that this system could be deployed for a fraction of the cost of on-scene epidemiological investigators to conduct sentinel surveillance in targeted risk areas, especially where zoonotic transmission is particularly likely. Included would be areas of human intrusion into those with target wild animal species (bats, primates) but also industrial animal production facilities for chickens and pigs, where infectious outbreaks have become epidemic, as occurred recently on a North Carolina poultry production factory. As noted, most people residing in these areas have cell phones with service, making ongoing surveillance feasible, given adequate protection of privacy and confidentiality.

While this proposed system can serve as a sentinel surveillance system, it can also act as an ongoing monitoring system of individual and population health and be used to evaluate response to clinical treatment without expensive and time consuming outpatient visits. We have proposed this approach as an Extensive Care System,(Drury, 16) rather than the typical Intensive Care System associated with ER visits, which have become de facto healthcare for many individuals. Like the apocryphal Star Trek Tricorder, this device can carry out ongoing monitoring of not only health status, but functional ability. The cell phone mediation path also allows for two way voice communication when indicated and the provision of health behavior prompts as well. While the existing hardware is limited to the parameters described above, new innovations in sensor technology are occurring daily and other parameters such as EEG, blood sugar levels, and mobility of elderly and disabled individuals. Innovations in materials design and biomedical engineering are driving the development of such a system forward and ay soon make possible an implanted device using body chemistry for power, thus being entirely unobtrusive and need on intermittent if any maintenance.Given the implications for health promotion and disease prevention, health insurers may reward insureds who use such a system with incentives such as reduced premiums.

Policy Implications:

Given the proviso described above regarding the role of psychological biases provided by common heuristics (Kahneman, 17), several policy implications have been developed, partly through the IHME's Delphi Consensus project (18). Investment in international agreements and enforceable treaties regarding transparent reporting of outbreak occurrences is essential as is the development of robust sentinel surveillance systems as described here. Firm government and citizen action is necessary to restrain the well organized and funded disinformation campaigns which have interfered with accurate public health, and indeed other scientific information necessary for a healthy and thriving culture. Adequate funding for research and development and institutional strengthening is also essential. The essential role of Non-Medical Intervention, particularly masking and distancing, has been shown repeatedly to be highly effective in slowing or stopping aerosolized pathogens such as SARS Cov-2 must be effectively encouraged and implemented, as has been done in historical and current outbreaks. Finally, application of relevant psychological science to encourage civility and citizen engagement and combat disinformation is necessary to heal the many divisions that have been fomented in many nations in the last generation.

References

1. Wilson, EO 2012 Consilience New York: Vintage.
2. Hood, L. P4 Medicine and what 21st century medicine should be. 2022. mYouTube.com.
3. Drury R., Jarczok, M, Owens, A. and Thayer, J. 2021. Wireless Heart Rate Variability in Assessing Community COVID-19. Frontiers in Neuroscience. 15:564159. doi:10.3389/fnins.2021.564159.
4. Wilson, DS 2019. Completing the Darwinian Revolution. New York: Pantheon.
5. Bowlby, J 2005. A secure base. London: Routledge.
6. Capra, F and Luisi, P. 2012 The Systems View of Life. Cambridge: Cambridge University Press.
7. Mitchell, S 2009 Complexity. New York: Oxford University Press.
8. Sole, R and Goodwin,D 2004 Signs of Life. New York: Basic.
9. Drury, R., Porges,S. Thayer, J and Ginsberg, J. 2019. Heart rate variability health and well-being: A systems perspective. Frontiers in Public Health. 7, 323. doi:10.3389./fpubh/2019.00323.
10. Shaffer, F. and Ginsberg, J 2019. An overview of heart rate variability metrics and norms. Fron. Public Health, 5:258. doi:10.33389/fpubh.2017.00258.
11. Dean, J. (2022) Asynchronous distributed data flow for ML. https//arxiv.org.
12. Topol, E. 2021 Deep Medicine. New York: Basic.
13. Jarczok, M , Koenig, J. Witting, A. Fischer, J and Thayer, J. 2019. First evaluation of an index of low vagally mediated heart rate variability as marker of health risks in human adults: Proof of concept. J. Clinical Med. 8:E1940. doi:10.3390/jcm8111940.
14. Porges, 2011, The Polyvagal Theory. New York: Norton.
15. Thayer, J. and Lane, R 2020. A model of neurovisceral integration in emotion regulation and dysregulation. J Affective Disorder, 61.201-216. Doi: 10.1016/So165-0327(00)00338-4.
16. Drury, R 2014. Wearable biosensor systems and resilience: A perfect storm? Front Psychology. doi:10.33889/fpsyg.2014.00853.
17. Kahneman, D. 2011.Thinking fast and slow. New York: Farrar, Straus and Giroux.
18. Institute of Health Metrics and Evaluation, A multinational delphi concensus to end the COVID-19 public health threat. Nature. November 2022. Doi: 10.1038/s41586-022-05398-2.